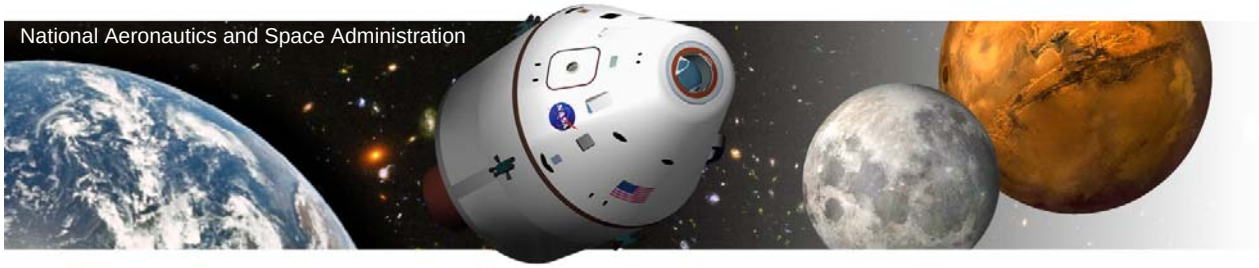

Leaving Your Competition in the Dust!

9-12 National Science Standards - Key Concept(s):
Physical Science, Earth and Space Science – Friction, Characteristics of Moon Dust

Purpose:
Ever get that "Earth is too crowded" feeling and wonder what life would be like on the Moon? NASA scientists and engineers are studying that right now. However, before you sign up for the three day journey, you might want to know a little more about your destination and what there is to do for fun once you arrive. Pack your winter sports gear… maybe you'll go "dustboarding" (Physics, Space Science, Geology).

Featured Imagery Component:
http://brainbites.nasa.gov/cab720

Educator Insights:

Friction:

1. Whether "boarding" on the Earth's snow or on the Moon's dust, friction will always try to slow the rider. Friction between objects is caused by surface irregularities, or asperities, that interfere with one another upon contact. The amount of friction depends on the types of materials in contact, their surface finishes, the amount of force pressing them together, and the amount of force exerted on the objects in an effort to make them slip or slide past one another. On a microscopic level, all surfaces are rough and uneven. Thus, whenever objects touch and are attempting to move relative to one another, friction is present.

2. Friction is a force and the amount of frictional force acting on an object is partially dependent on the *coefficient of friction,* **μ**, between the object and the material it is touching. Generally speaking, **μ** = **F/N** where **F** is the tangential force required to cause sliding and **N** is the normal force between the surfaces. The normal force, **N**, is often a function of gravity. In fact, when an object is on a flat surface that is perpendicular to the pull of gravity, **N** = **m*g,** where **m** represents the object's mass and **g** is the local gravitational acceleration. For a dustboarder on the Moon or a snowboarder on the Earth, the normal force, and therefore the friction, will be a function of the slope of the hill, the local gravity, and the mass of the rider. The hill's slope converts the weight of the rider into a tangential force component that pulls her down the hill and a normal force component that pushes her normal to the hill.

3. There are two basic types of friction, *static friction* and *sliding friction*. Most of the time, static coefficients of friction are higher for a pair of materials than sliding coefficients of friction, but this is not always the case. NASA engineers calculate *static* friction when they need to know how much force it will take to slide an object that is at rest, for instance, a boarder that is stopped near the crest of a hill. Similarly, they calculate *sliding* friction to figure out how much force the snow or Moon dust will exert on the board when it slides down the hill.

4. The force of friction acting against a sliding object affects how quickly the object will slow down or *decelerate*. In the case of dustboarding, characteristics of both the board and the lunar dust will determine the resulting coefficient of sliding friction. A wooden dustboard might be slower on the Moon than a Teflon-coated dustboard of similar size, shape, and weight simply because of the unique coefficient of friction between it and Moon dust. Likewise, one would expect the coefficient of friction to be different when using the same board on different types of dust or snow. How might an athlete's boarding skills be affected if the Winter Olympics were on the Hadley region of the Moon instead of the snow-covered mountains near Torino, Italy? What about boarding on the red dirt of Mars?

5. Coefficients of friction generally fall between zero and one; however, some combinations of materials have coefficients *greater* than one. For example, aluminum in contact with aluminum can have coefficients of friction ranging from 1.0 to 1.4. Factors such as humidity and surface cleanliness can noticeably affect coefficients of friction, along with a host of other parameters. Unlike Earth, the Moon has no atmosphere or humidity. It is interesting to note that the absence of air and humidity can actually cause some metallic objects to "weld" together upon contact. To prevent such occurrences, NASA carefully chooses materials that will not stick together in the vacuum of space. Sometimes this is achieved with Silver plating or special coatings containing Molybdenum (*mo-lyb-de-num*) Disulfide, which are two "dry" lubricants used on bolts in space.

6. Imagine if an Olympic snowboarder were to slide straight down a hill covered in Moon dust in Torino, Italy and then slide down an identical dust-covered hill on the Moon, which run would be faster? To calculate the answer, a person must consider how gravity affects each situation. Earth's gravity is roughly 9.8 m/s^2 while the Moon's is approximately $1/6^{th}$ of that or 1.6 m/s^2. While the Moon's reduced gravity should equate to less friction than on a similar dust-covered hill on Earth (remember that friction is proportional to an object's weight), gravity also affects the overall rate of acceleration down the hill. However, the answer depends on more than just how gravity affects friction and acceleration. Do not forget to account for the aerodynamic drag forces here on Earth that would not be present on the Moon. Additionally, the presence of air on Earth could reduce the friction between the board and the dust as compared to the Moon. There are a lot of things to think about before returning to the Moon and going on to Mars. What other factors might NASA need to consider?

Characteristics of Moon Dust:

7. Lunar dust consists of extremely fine, powder-like particles. The correct terminology for lunar dust is *regolith* (*reg-o-lith*). Regolith is the Moon's fragmented layer of particles that covers its surface. These particles are typically smaller than 1 centimeter in diameter and blanket the Moon's bedrock. Regolith consists of broken and melted debris and the portions referred to as "dust" are only the smallest, most finely shattered regolith particles. Regolith is unlike any naturally occurring substance on Earth. For the last three to four billion years the Moon has been bombarded by a wide range of objects, from asteroids as large as tens of kilometers in diameter to particles of cosmic dust just a few hundred Angstroms or one nanometer in size. These impacts form craters and shatter, pulverize, melt, mix, and disperse lunar rock. The resulting Moon dust is a light to dark grey, fine-grained, loose material that averages 60-80 micrometers in size.

8. Localized heat generated by impacts can melt regolith and turn it into a glass-like substance. Glass is also formed in volcanic eruptions and is eventually broken into small irregular pieces. These bits of glass are very sharp and abrasive. On Earth, water and wind wear down the sharp edges of minerals. However, on the Moon there is no water or air to erode these particles and they remain sharp indefinitely. Impacts can also *increase* the size of dust particles by melting glass and dust particles together into strange forms called *agglutinates* (*ag-glu-ti-nate*). Some agglutinates take on fascinating shapes with narrow bridges, delicate necks, and tiny, thread-like arms. Others may be circular, elongated, and full of blisters.

9. Dust particles on the Moon store electricity by building up a static charge. It is similar to the static electricity that develops when people rub balloons against their head. Just as hair sticks to the balloon, charged Moon dust sticks to many surfaces. What does this mean for NASA? If too much dust accumulates on equipment used to explore the Moon's surface the mission might end early. This dust can wear down surfaces, damage seals, prevent solar panels from generating enough electricity, and hinder heat exchangers from being able to reject enough heat. All these consequences could hamper science and exploration activities on the Moon, or even endanger the crew's lives. Scientists and engineers at NASA are currently planning human missions to the Moon and they continue to explore ways to cope with the challenges of lunar dust.